## Technical Description for Parking Facilities

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Background

Since the inception of the Benchmarking Tool in January 1999, users have been able to include parking facilities (parking lots, above ground garages, and below ground garages) in the characterization of their buildings. Initially, this was accomplished through the use of engineered values, which simply related the energy impact of these various parking facilities to their size ($ft^2$) and operation (weekly hours). The estimated energy impact of the user's parking facilities were then incorporated into the customized range of total building energy intensity values corresponding to scores ranging from 1 to 100. In the case of garage space where it contained actual vertical and horizontal dimensions, the energy impact was weight-averaged with the remainder of the building space. For parking lots, only the energy impact (generally the lighting) was included, and not the associated area of the lot. While this method served us and our users well, an improved method for handling parking facilities – actually just above-ground and below-ground parking garages – was identified.

Using energy consumption and building characteristics data collected by the Energy Information Administration (EIA) for their Commercial Building Energy Consumption Survey, a simple model was created which related the energy consumption of parking garages to several operational and physical characteristics of the structures.

Parking Facilities

Within Portfolio Manager users can account for the energy impact of their parking facilities including open parking (parking lots) and parking garages, both above ground and below ground. These parking facilities are intended to account for the energy impact associated with buildings in which cars are parked. Excluded from this definition are service garages or garages with operational service bays.

These parking facilities are intended for the exclusive use with the other primary building types; currently office, K-12 schools, supermarket/grocery store, and hotel/motel. As such, the energy performance of parking facilities themselves cannot be benchmarked, nor are these structures eligible for the ENERGY STAR® label.

**Special Note**: Unattached garages or open parking facilities which are wholly sub-metered are considered structures onto themselves and, as such, should not be included as part of the benchmarking assessment of its associated building with Portfolio Manager.

Parking Facilities – Open Parking

Buildings containing a lighted open parking lot *not separately metered* are assigned a power density of 0.025 Watts per square foot ($W/ft^2$) for the purposes of calculating ENERGY STAR target values and benchmarking. This energy consumption allowance is derived, as discussed in the paragraph that follows, using established engineering standards for lighting power allowance. The total power density multiplied by the estimated annual operating hours results in an annual energy consumption that is included in the overall ENERGY STAR benchmarking target.

For open parking lots, IESNA recommended minimum and average illuminance levels for vehicle and pedestrian low activity were assumed, with a recommended average-to-minimum uniformity ratio of 4:1 or less. Reasonably efficient equipment with good color rendition and glare control was all assumed (flat lens Type III or Type V, 70%

efficient luminaries, with either metal halide or high pressure sodium lamps), with a design based on either 18 or 30 foot-high poles. The power density allowance to meet these service requirements is 0.025 W/ft$^2$. Operating 84 hours per week, the maximum allowable for open parking lots, the annual energy for the outdoor lighting system would be 0.1 kWh/ft$^2$-year.

The following expression describes the annual source energy impact relationship, in kBtu/year, for open parking facilities:

$$\text{Source}_{\text{Open}} = \text{AreaOpen x (Weekly Hours x 52) x 0.025 W/ft}^2 \text{ x 10.3 kBtu/1000 W}$$

$$\text{Source}_{\text{Open}} = \text{AreaOpen x Weekly Hours x 0.013395 kBtu/hr-yr-ft}^2 \qquad \text{Equation (1)}$$

**Example #1**
Parking Lot
On Same Utility Meter
Area = 10,000 ft$^2$
Weekly Hours = 84

Using Equation (1) above, the annual energy impact of this open parking facility, is given as:

$$\text{Source}_{\text{Open}} = \text{10,000 ft}^2 \text{ x 84 hours x 0.013395 kBtu/hr-yr-ft}^2$$

$$\text{Source}_{\text{Open}} = \text{11,251.8 kBtu/yr}$$

Parking Facilities – Ventilated and Unventilated Garages

Buildings containing a covered parking garage (lighted and mechanically ventilated, or lighted and unventilated) *not separately metered* have a power density calculated based on historical data for the purposes of calculating ENERGY STAR target values and benchmarking. This energy consumption allowance is derived, as discussed in the paragraphs that follow, using the 1992 CBECS for garage energy intensity. The total energy intensity is calculated using a using a regression model equation that relates garage energy intensity to the significant drivers of energy intensity. Results are included in the overall ENERGY STAR benchmarking target.

For parking garage structures, garage energy consumption and characteristics data from the 1992 CBECS were used to develop a simple regression model relating energy intensity to the major drivers. The 1992 CBECS is the most comprehensive dataset available and was the last CBECS survey to specifically include energy consumption and characteristics data for parking garages, thus the rationale for not using the 1995 or any subsequent dataset.

The 1992 CBECS contains data for 112 individual records identified as parking garages. The following filters were applied to remove suspicious records and result in a more homogeneous dataset:

- Area > 4,999 ft$^2$;
- Area < 1,000,000 ft$^2$;
- Heating Degree Day (HDD) + Cooling Degree Day (CDD) > 0;
- Electricity consumption > 0; and
- Months in use > 10.

Application of the above filters reduced the number of individual records from 112 to 67. Using the data associated with the remaining 67 records, a regression model was developed for the purpose of relating garage energy intensity to its most significant drivers of energy intensity which were found to be the following:

- CDD;
- HDD;
- The natural log of Area ($ft^2$);
- # of Floors above ground;
- # of Floors below ground;
- Weekly operating hours; and
- Occupant (worker) density (# of Workers/1,000 $ft^2$ of garage area)

The garage source energy intensity (Source $EUI_{50}$) associated with the $50^{th}$ percentile, the mean garage source energy intensity (Source $EUI_{Mean}$) and the regression equation, Equation (2) are as follows:

Source $EUI_{50}$ = 53.02 kBtu/$ft^2$-year

Source $EUI_{Mean}$ = 76.36 kBtu/$ft^2$-year

Source $EUI_{Predicted}$ = 435.6458665 - 0.03746486 x CDD - 0.021370974 x HDD - 29.2205414 x Ln(Area) + 3.948040792 x # of Floors Above Ground + 19.58786414 x # of Floors Below Ground + 0.54456671 x Weekly Hours + 298.6307576 x # of Workers/1,000 $ft^2$ Equation (2)

The mean garage source energy intensity is provided only as a reference point. The resulting source energy calculated by the equation above is the incorporated into the overall ENERGY STAR benchmarking target weighted by floor area.

Garage Energy Impact
Using the values and equation above, the annual energy impact ($Source_{Garage}$), in kBtu/year, associated with a parking garage is given by the following equation:

$Source_{Garage}$ = Source $EUI_{Predicted}$ x (Source $EUI_{50}$ / Source $EUI_{Mean}$) x $Area_{Garage}$

$Source_{Garage}$ = Source $EUI_{Predicted}$ x (53.02/76.36) x $Area_{Garage}$
$Source_{Garage}$ = 0.694 Source $EUI_{Predicted}$ x $Area_{Garage}$ Equation (3)

**Example #2**
Garage
Attached, Above Ground, On Same Utility Meter
CDD = 1500
HDD = 2000
Area = 10,000 $ft^2$
# Floors Above = 4
# Floors Below = 0
Weekly Hours = 90
Workers = 1

Using Equation (2) above, the predicted source energy intensity is:

Source $EUI_{Predicted}$ = 162.2 kBtu/ft$^2$-year

Thus, the energy impact associated with the garage space is given by Equation (3) as:

$Source_{Garage}$ = 0.694 x (162.2 kBtu/ft$^2$-year) x 10,000 ft$^2$

$Source_{Garage}$ = 1,125,668 kBtu/year

<u>Assessing Performance: Incorporating the Energy Impact of Parking Facilities</u>

The energy impact, in kBtu/year, of garage space and open parking is calculated and is added to the impact of the primary (i.e. office, K-12 school, etc.) space. Once done, this value is then divided by the total area of the primary space which includes the area associated with any computer room and data center space. At this point, a column of customized Source EUI values corresponding to scores ranging from 1 to 100 are created as shown below. The weather normalized actual energy intensity of the user's building is then compared to this column of values to determine the appropriate score. The following example shows how this is accomplished.

To assess the performance of a building on the 1 to 100 scale, two calculations are made upon the user entering in the requisite data. First, as explained in the Weather Normalization file (downloadable at www.energystar.gov), the user's actual annual source energy intensity, in kBtu/ft$^2$-yr, is weather normalized to reflect the annual source energy intensity the building would have seen in a normal (i.e. 30-year average) weather year. In the second calculation, the regression model equation is used to calculate a predicted source energy use intensity, Source EUI, value based on the operating characteristics entered by the user. This predicted Source EUI is then divided by the mean Source EUI of the regression model; yielding an adjustment factor. The adjustment factor is then applied to each of the Fitted Source EUI values corresponding to scores from 1 to 100 to provide a range of Customized Source EUI values. Multiplying each of the customized Source EUI values by the area of the building results in the annual source energy consumption values corresponding to scores from 1 to 100 for the building in question. The area of the building in this case is inclusive of office space, K-12 school space, and computer room/data center space, but is exclusive of all parking facility space – garages and parking lots. Next, the annual source energy consumption of the parking facilities is calculated, summed, and added to the customized annual source energy values calculated previously to give total annual source energy consumption values for the 1 to 100 scores. These values are then simply divided by the building's area, as defined above, to yield Source EUI values inclusive of the parking facility energy impact corresponding to scores ranging from 1 to 100. Finally, to calculate the score of the building, the building's weather normalized Source EUI is compared to the table of Customized Source EUI values.

Table-1 is intended for use with the following example to illustrate how a score is determined for a given building. In this example, the actual Source EUI was weather normalized up approximately 3%; in essence meaning that over the course of the year in which the building's energy consumption was reported the building "experienced" a net 3% milder weather year than normal.

**Example #3**

Office Building with parking garage and parking lot

Actual Annual Source Energy Consumption = 12,800,000 kBtu/yr
Weather Normalized Annual Source Energy Consumption = 13,200,000 kBtu/yr

Weather Normalized Source EUI = 13,200,000 kBtu/100,000 $ft^2$

Weather Normalized Source EUI = 132.0 kBtu/$ft^2$-yr ←

Office Space
100,000 $ft^2$
Occupants = 200
PCs = 200
CDD = 1500
HDD = 2000
Weekly Hours = 55

Predicted Office Source EUI = -42.215 + 14.967 x Ln(Area) + 0.0116 x CDD+ 0.517 x Hours + 16.766 x OccDensity + 9.759 x PCDensity

Predicted Office Source EUI = 229.0 kBtu/$ft^2$-yr

Mean Office Source EUI = 201.7 kBtu/$ft^2$-yr

Adjustment Factor, $AF_{office}$ = Predicted Source EUI / Mean Source EUI = 229.0 / 201.7
$AF_{office}$ = 1.136

Parking Lot Space
On Same Utility Meter
Area = 10,000 $ft^2$
Weekly Hours = 84

$Source_{Open}$ = 11,225.76 kBtu/yr (from Example #1 above)

Parking Garage Space
Attached, Above Ground, On Same Utility Meter
Area = 10,000 $ft^2$
Workers = 1
CDD = 1500
HDD = 2000
# Floors Above = 4 (# Floors Below = 0)
Weekly Hours = 90

$Source_{Garage}$ = 1,125,668 kBtu/yr (from Example #2 above)

Total Source Energy Impact due to Parking Facilities,
$Source_{Parking} = Source_{Garage} + Source_{Open}$
$Source_{Parking}$ = 1,125,668 kBtu/yr + 11,225.76 kBtu/yr

$Source_{Parking}$ = 1,136,894 kBtu/yr

**Table-1 Determining Benchmarking Score**

| Score | Fitted Look-Up Source EUI Value (kBtu/ft$^2$-yr) | Adj. Factor | Adjusted Office Source EUI (kBtu/ft$^2$-yr) | Office Source Energy Impact (kBtu/yr) | Parking Source Energy Impact (kBtu/yr) | Total Source Energy Impact (kBtu/yr) | Weighted Adjusted Source EUI (kBtu/ft$^2$-yr) |
|---|---|---|---|---|---|---|---|
| 100 | 47.42 | 1.136 | 53.86 | 5,385,668 | 1,137,227 | 6,522,896 | 65.23 |
| 99 | 56.59 | 1.136 | 64.27 | 6,427,079 | 1,137,227 | 7,564,306 | 75.64 |
| 98 | 63.05 | 1.136 | 71.60 | 7,160,178 | 1,137,227 | 8,297,406 | 82.97 |
| … | … | … | … | … | … | … | … |
| … | … | … | … | … | … | … | … |
| … | … | … | … | … | … | … | … |
| 85 | 104.73 | 1.136 | 118.94 | 11,893,511 | 1,137,227 | 13,030,738 | 130.31 |
| 84 | 106.99 | 1.136 | 121.50 | 12,150,476 | 1,137,227 | 13,287,703 | 132.88 |
| 83 | 109.20 | 1.136 | 124.02 | 12,401,565 | 1,137,227 | 13,538,793 | 135.39 |
| … | … | … | … | … | … | … | … |
| … | … | … | … | … | … | … | … |
| … | … | … | … | … | … | … | … |
| 1 | 537.21 | 1.136 | 610.09 | 61,008,666 | 1,137,227 | 62,145,893 | 621.46 |